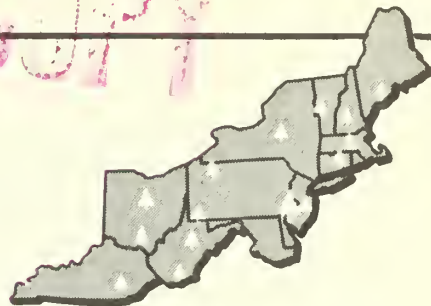


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GRAY SQUIRRELS REPRODUCE IN A 2-ACRE ENCLOSURE

Abstract. — A 2-acre enclosure was built in a 40-year-old hardwood stand, and 5 to 19 gray squirrels (*Sciurus carolinensis*) were confined in it during 3 years. Reproductive behavior of the squirrels was the same at all population densities, but densities above 12 may have reduced productivity. For 10 to 12 squirrels, behavior was about normal and productivity was high. At population levels above 12, antagonistic behavior and fence-running increased. The enclosure was modified until escapes were reduced to less than 10 percent per year. Disease and predation were not a problem. Fence costs were \$2,000 for materials and about 125 man-days of labor. The enclosure proved practical for squirrel research.

The gray squirrel (*Sciurus carolinensis*) can be accommodated in a small area, has known food habits, and will accept commercially prepared food. He is tolerant of man and can be trapped, handled, and tamed fairly easily. But there is one difficulty: the gray squirrel does not reproduce readily in confinement (*Shorten 1951-1952*). We thought a large outdoor enclosure might allow normal reproduction; and, on the basis of work in Ohio (*Donohoe 1965*) and Florida (*Moore 1957*), we selected 2 acres as a likely size.

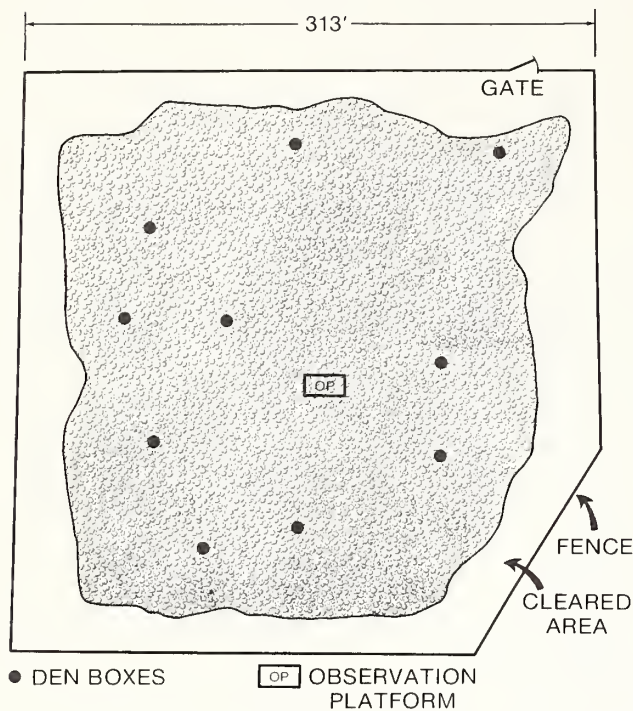
Our initial objectives were to design and test an escape-proof enclosure, to determine how many squirrels could be maintained without producing manifestations of overpopulation, and to determine if reproduction would occur.

This is a report on design and use of the enclosure and includes only limited data on squirrel behavior.

ENCLOSURE AND METHODS

An area of immature but potentially good squirrel habitat was selected in the West Virginia University Forest, 11 miles east of Morgantown. The stand is mixed hardwoods about 40 years old, with low mast production and few den sites. A relatively flat site was chosen — to give maximum effectiveness to the height of the fence. To prevent squirrels from crossing the fence via tree canopies, we cut and removed all trees with canopies above a 30-foot-wide strip centered on the fence line. The total area enclosed was 2.1 acres, including 1.5 acres of tree canopy (fig. 1).

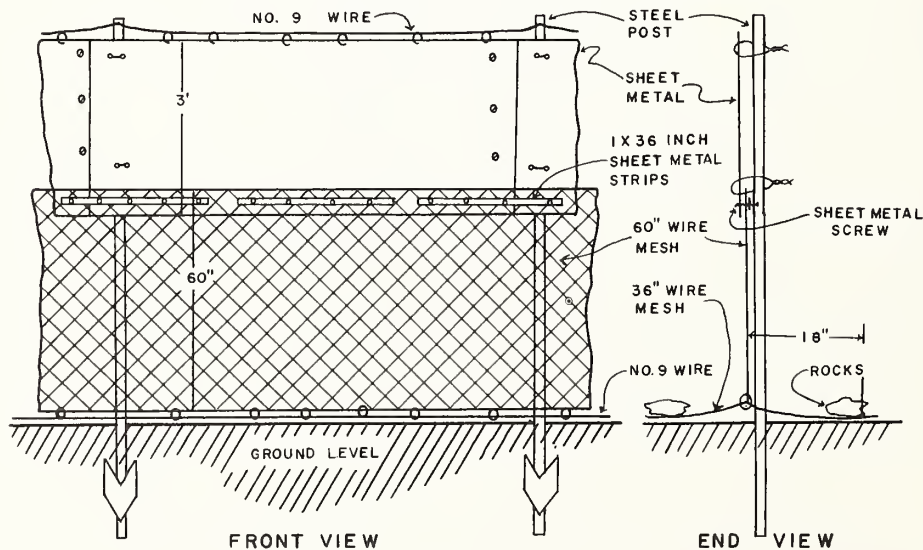
Figure 1.—Diagram of the 2-acre squirrel enclosure.



The squirrel-proof fence was about 7.5 feet high with a 3-foot strip of sheet metal attached above a 5-foot high base course of 1-inch mesh wire (fig. 2). It was not practical to bury the bottom of the fence, because the soil was very rocky. Therefore 3-foot-wide 1-inch mesh wire was laid on the ground and attached to the bottom of the fence to prevent animals from going underneath (fig. 2). Materials cost approximately \$2,000, and about 125 man-days were used in building the fence. Construction details and recommendations can be obtained by writing to the USDA Forest Service, Forestry Sciences Laboratory, 180 Canfield Street, Morgantown, W. Va. 26505.

We plugged the natural dens and installed den boxes (*Barkalow and Soots 1965*), because it would be easier to check litters and capture squirrels in the boxes than in natural tree-dens. Six den boxes were placed 20 to 25 feet up in trees scattered throughout the enclosure. More boxes were added when needed to provide one more den box than the squirrels were regularly using. All den-box entrances were visible from an observation platform constructed about 10 feet up in a tree near the enclosure center (fig. 1). We did not interfere with leaf nest construction and maintenance.

Figure 2.—Detail sketch of the squirrel-proof fence.



Natural foods were supplemented with corn and laboratory rat chow as needed. Drinking water was supplied, and the squirrels used snow or ice during freezing weather.

Squirrels were marked with numbered, self-piercing, monel fingerling tags in each ear, and with colored plastic-impregnated nylon collars $\frac{1}{2}$ inch wide. Some collars were chewed off and some caused neck infections. Consequently, collars were abandoned in favor of marking the fur with Nyanzol D dye from Nyanza, Inc., Lawrence, Mass. (The use of a trade name is for the information and convenience of the reader, and is not an official endorsement or approval by the U. S. Department of Agriculture.)

Observations of behavior were made to evaluate the effects of the enclosure on the introduced populations. The squirrels were periodically recaptured in box traps and den boxes for examination and re-dyeing.

External parasites were controlled by dusting the boxes and squirrels with rotenone. Coccidiosis was the only disease problem; this was controlled by adding a sodium sulfamethazine coccidiostat to the drinking water at the manufacturer's recommended dosage for poultry.

No losses to predation were observed or suspected; however, we saw a red-tailed hawk swoop unsuccessfully at a squirrel, and two rattlesnakes were removed from the enclosure.

The introduced squirrels were trapped in Maryland, West Virginia, and Pennsylvania. Age estimates were made, using the techniques of Uhlig (1955) and Barrier and Barkalow (1967). Adults were defined as those capable of breeding. Females generally breed at about 12 months and males at 17 months (Horwich 1967).

SQUIRREL BEHAVIOR AND REPRODUCTION

The evaluation was divided into three time periods: (1) November 1969 to August 1970 — low population, (2) September 1970 to August 1971 — high population, and (3) September 1971 to July 1972 — medium population.

November 1969 to August 1970 — Low Population

Three adults — two males and one female — were introduced in November. A subadult pair was introduced in February, and an adult pair was introduced in March. Of the six den boxes available, only three were used. The squirrels denned together by release groups, except for two loners.

Some fence-running occurred immediately after each introduction, but it was not excessive and soon ceased except for occasional exploration of the fence. Three squirrels that had been captured in the immediate vicinity did more fence-running than the others. Perhaps their familiarity with the surrounding area stimulated extra effort to escape from the pen.

By May two squirrels were missing. One female was recaptured outside the enclosure and was returned four times without our discovering her escape route. The other squirrel was never accounted for. Later in the summer, another squirrel escaped and was recaptured. We assumed that the squirrels had escaped over sections of the fence that had wooden cross braces. Therefore we moved the braces from below to above the sheet metal. But the problem was not completely solved until a sheet-metal shield was installed under the braces in July 1972 (fig. 3).

Pre-mating behavior began in April, and mating chases were observed in May and June. The first known litter, born in July, was successfully reared and remained in the enclosure until the following summer. The mother was probably the only breeding-age female in the pen. The key event was the birth and survival of a litter.

September 1970 to August 1971 — High Population

The next objective was to determine how many squirrels could be maintained satisfactorily in the enclosure. The residual group of 7 (5 adults and 2 juveniles) was increased to 19 by introducing 2 groups of 4 subadults (2 males, 2 females) in December and March, respectively. A group of 4 squirrels — 3 adults (1 male, 2 females) and a subadult male —



Figure 3. — Completed corner of squirrel-proof fence. Note the metal shields under the wooden braces and the wire cross bracing below the 3-foot-wide sheet metal.

was introduced in July. The maximum density attained was probably 17.

No squirrels were added until those of the previous introduction had integrated with the earlier residents.

We judged the effect of each new introduction on the residents by looking for behavioral changes, such as an increase in aggression, fence-running, and re-establishment of a social hierarchy. Reproductive behavior was also noted.

Mating chases began in mid-May, and the first litter was born in early July, by the same female that had borne a litter the previous year. When the young were 4 weeks old, they were ear-punched for identification, but the marks disappeared by age 8 weeks. Then the ears were large enough for tagging. Three more litters were born in late July. When the young were less than 10 days old, they were toe-clipped, since their ears were too small to punch. The late-July litters were subsequently destroyed, probably by the mothers. Two other females behaved as though they had litters, but we never found the young.

After the second group of squirrels was introduced, in March, we saw some behavioral signs of overpopulation. The number of squirrels running along the fence increased. The fur on a few squirrels appeared dull and rough, versus smooth and glossy coats on healthy squirrels; and several squirrels had indications of diarrhea — a symptom of coccidiosis. Squirrels started to escape through holes in the rusted 20-gage wire net in May; and despite repairs, 12 were lost by September 1. These escapes prevented a full evaluation of the July introduction. However we hypothesized that this introduction of 4 squirrels, raising the total number to 17, may have contributed to the litter destruction.

We concluded that 10 to 12 squirrels would be a reasonable density in our 2-acre enclosure.

September 1971 to July 1972 — Medium Population

The rusted wire net (20-gage 1 x 1 inch) was replaced with a heavier material (14-gage

1-inch wire mesh), and the enclosure was readied for restocking. There were 7 squirrels remaining in the enclosure, and we brought the population up to 12 (5 males and 7 females) by March 1.

Two litters were born in early May—earlier than previous litters born in the enclosure. By mid-July a third litter was born and a fourth female was pregnant (determined by palpation).

The three litters were checked when less than 10 days old; one squirrel from each litter was removed for age determination and then returned. The two early-May litters were not disturbed again until age 6 to 7 weeks, when they were examined, weighed, and ear-tagged on June 7. In mid-July they were removed from the enclosure to reduce the population. All had been weaned by then and were healthy and active.

CONCLUSIONS

Gray squirrel reproduction was not inhibited by the 2-acre enclosure, but litter survival

was reduced at the highest population levels.

Toe-clipping the young squirrels may have triggered their destruction by the mothers. Although toe-clipping has been successfully used to mark unconfined nestling gray and fox squirrels (*Sciurus niger*) (Bakken 1952; Baumgartner 1940; Barkalow et al. 1970), one confined litter of fox squirrels was killed by their mother immediately after they were handled and toe-slipped (Charles Nixon, personal communication). In our study, the addition of the last group of squirrels may have produced sufficient population stress to provoke this behavior. Litter survival was excellent the following year, but only 12 adult squirrels were present in the enclosure then, and no toe-clipping was done.

A population of 10 to 12 squirrels appears to approach optimum density for this 2-acre enclosure.

We believe escape problems have been reduced to the minimum possible with our enclosure design and that it is suitable for many kinds of squirrel research.

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